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VARIABLE STAR OBSERVING IN NEW ZEALAND

By Frank M. Bateson
Astronomical Society of New Zealand

History. The years 1927–28 saw a quickening interest amongst New Zealand amateurs in serious astronomical observing and observing sections were formed to encourage work on a systematic basis in several fields, including Variable Stars.

Prior to the formation of a Variable Star Section, spasmodic observations had been made by New Zealand amateurs, notably C. J. Westland. In the main such observers had worked in isolation, without any set plan and without more than casual contact with other workers in the same field. The origin of the Section was actually due to encouragement and direction received from professionals and amateurs during a four year stay by the writer in Sydney, Australia. It was there that he commenced what has become a life interest.

On returning to New Zealand in 1927 an appeal was issued in August for observers. The response was gratifying and a sub-section of the Southern Variable Star Section of the N.S.W. Branch of the British Astronomical Association was formed. Until 1928 June 30 all results were sent to Sydney and published there. But the growth of the N.Z. Section was such that an independent body was formed, as an observing section of the Astronomical Society of New Zealand.

At first observations were confined to 19 variables, mainly of the Mira Ceti type, and including all the best know southern variables. The same stars were under observation in Australia. In 1928 September an additional 20 stars, also of long period, were added to the working list. Since then the observing list has grown steadily, until it now includes 328 variables. These stars are divided amongst the various classes as follows: Mira Ceti type, 201; Semi-regular, 19; RV Tauri type, 19; U Gem type, 16;

R CrB type, 15; Novae, 10; Nova-like, 12; Unknown, 12; Miscellaneous, 24. In addition a number of suspected variables are observed. The list is being added to from time to time.

Naturally, like most amateur observing sections, we have had our ups and downs, especially during the formative years. Records also fell off during the war, as most of our members were serving with the armed services. Whilst totals are not everything, they do provide some index of the progress made. Up to the end of 1940, there had been made 35,379 observations distributed amongst 35 observers. The actual records were published (Bateson, 1929–41) and later fully discussed (Bateson, 1944).

As a result of the war there were few records from 1941 to 1943, but thereafter observations increased rapidly. To the end of 1957 the total is well over a quarter of a million, excluding observations of suspected variables for which there are several thousand additional records. The most outstanding observer is Albert Jones, of Timaru. For some years he has averaged 10,000 observations annually and has amassed a grand total of 100,000. This is a record, which is remarkable for its numbers and also for the skill and accuracy shown. The writer, over a much longer period, has recorded some 25,000 observations in addition to running the Section. The third most prolific observer was Gordon Smith, of Dunedin, with a total of 15,827 observations in the pre-war years.

One of our members, A. G. Crust, was an independent discoverer of Nova Puppis (Crust, 1942). Observations and light curves of this bright nova, from pre-maximum to mag. 13.0 were published by the Section (Bateson, 1950). Observations have continued since and several other novae and recurrent novae are followed. Several variable stars have been discovered by members.

Composition. The New Zealand Variable Star Section has been modelled partly on the A.A.V.S.O. and partly on the observational sections of the B.A.A. Its membership is drawn from the ranks of its parent body, the Royal Astronomical Society of New Zealand, and astronomical societies affiliated to it. The instrumental equipment of members includes reflectors of 6 inches to 12½ inches and refractors up to 8 inches. This year, a 16-inch professionally made Newtonian-Cassegrain reflector, is being added to the writer's own equipment.

The Section is headed by a Director, a post which the writer has occupied since he first formed the Section. It is my duty to do much the same routine work as is performed by the Director of the A.A.V.S.O. This involves the checking of the observers' records and their transfer into permanent ledgers, as well as the publication of the results.

All observations are plotted, as well as daily, five day or ten day means depending on the nature of the variation. Light curves are drawn and the mean light curves determined. In fact everything is done to extract the maximum information from the observations. There possibly has been one advantage in the methods used, in that all the data have been treated in a uniform manner by one person.

That it has been possible to perform all the routine tasks has been due firstly to the very close relationships that have been developed between the individual observers and the Director. The second reason is that the Section has been fortunate in having an unpaid Secretary who performs all the necessary mundane tasks which we all dislike so much: Mrs. Bateson has shouldered this burden without complaint for many years.

Strange as it may seem, the Headquarters of the Section are not in New Zealand proper. They are at my Observatory, in Rarotonga, a tropical island that forms the main centre of the Cook Group, a dependency of New Zealand and legally forming part of the Dominion. This has had many advantages, as long as one also has to earn a living from some other calling. Firstly, from the administrative viewpoint, it provides a base free from the distractions of modern civilization. With the more leisurely pace of island life it permits a very much greater amount of time to be devotd to the Section's work than the normal amateur can give. Secondly, from the observational aspect, it enables us to cover a wider field because of the range in latitude and longitude that it provides. This is particularly important in the study of U Gem stars and others that are subject to sudden fluctuations. Lastly, it has enabled the writer to carry the not inconsiderable costs of running the Section.

Publications. The Section publishes the observations quarterly by means of *Circulars*. These are distributed free to a very extensive mailing list throughout the world, so that the results are readily available to all those interested. In addition, other *Circulars* contain data on particular variables with discussion of the results. To date 83 *Circulars* have been issued, of which the first three comprised instructions and lists of stars. Separate from these were published detailed Instructions to Observers.

Reprints of the Annual Report to the parent Society and of papers published elsewhere are also distributed. *Bulletins*, or memoirs, containing a summary of the results over a decade or two form the other series of the Section's publications. Only one *Bulletin* has been issued so far. This was reviewed by others (Campbell, 1944).

International Co-operation. One of the fundamental aims of the Section has always been to make available its records in a manner in which they

can best be used by professionals. In addition, its services are also available to participate in observations of any particular variable, or group of stars, for which visual records are especially desired.

The first example of this co-operation was in 1933, when Leon Campbell sought our assistance in making visual observations of the two bright Cepheids, β Doradus and 1 Carinae. From 1933 September to 1936 February, 35 observers made 6,993 observations of these two stars. The results (Bateson, 1944) provided visual records for comparison with the photometric and spectroscopic observations. That it was possible to attain a high standard of accuracy is shown by comparison of the deduced periods with those obtained by other methods. For β Doradus a period of 9.846 days was deduced compared to 9.842603 days given in the *General Catalogue of Variable Stars* from other sources. For 1 Carinae the periods were respectively 35.491 days and 35.5323 days.

Since this initial programme, the Section has undertaken observations of many variables at the special request of overseas investigators, the latest being observations of various stars of the RW Aurigae type for Prof. Hoffmeister. Often results are supplied in advance of publication. For some stars, by request, we notify observers engaged in spectroscopic work of variations so that their programmes can be arranged.

Methods of Observation. Our methods are those common to the A.A.V.S.O. The fractional method of comparison has always been used. This has been essential since it is more accurate than other visual means when the magnitude intervals between successive comparison stars are usually in excess of the desired intervals.

We differ from the A.A.V.S.O. in one respect: Our observers record and report their observations in detail and such particulars are entered in the permanent records. This policy has been dictated by the state of sequences for southern variable stars. Many variables are observed long before the magnitudes of the comparison stars are available.

Charts and Sequences. The standards necessary for a sequence of comparison stars to follow has been well set out (Mitchell, 1935). Summarized, this means providing the amateur organizations with a chart showing a sequence of comparison stars, whose magnitudes cover the complete range of the variable from maximum to minimum, and extending to about half a magnitude brighter and fainter than these limits. Where possible, the chart should have brighter stars shown to aid identification, or else small finder charts should be distributed. The successive stars in a sequence should not differ by more than 0.3 or 0.4 magnitude.

The chart itself should show all the stars around the variable and the comparison stars necessary to make their identification certain. It should not, as is too often done, be overloaded with minute dots which are generally useless, since the stars they represent will be invisible in the average amateur's instrument. They only tend to confuse the observer. The ideal is very well represented by many of the A.A.V.S.O. charts (d) and (e), incorporating the revisions made at the Leander McCormick Observatory.

An additional and most important point is that for each variable there should be one reliable sequence and this should be used by all observers. The magnitudes of the sequence should be on an international system.

Having stated the ideal, one can turn to the charts and sequences available for variables in the southern sky to see how they conform to the standards required. One is immediately confronted with the situation that, for all except a small proportion of variables south of declination $-30°$, visual sequences of any nature do not exist and charts have generally not been published.

The main authority for sequences is Harvard Observatory (Campbell, 1913) which published visual sequences for 92 variables south of $-30°$. The magnitudes were based on Bailey's photometric observations at Arequipa. The New Zealand Section has used photographic charts supplied by Campbell with these visual sequences marked thereon. The southern A.A.V.S.O. charts appear to be reproductions of Campbell's original charts without revision.

These sequences leave a great deal to be desired. Their defects can be summarized:

(1). The sequences often do not include stars as bright as the variable at maximum.

(2). Generally the variable is fainter—often very much fainter—than the faintest sequence star.

(3). The consecutive stars in most sequences differ in brightness often far in excess of the ideal limits. For a number the difference is a whole magnitude or more!

(4). The sequences contain many instances of substantial differences in assigned and actual magnitudes. Also occasionally there are wrong identifications.

(5). All sequences are generally unreliable below magnitude 11.

One must not blame the original observations for the defects. They could hardly be avoided at the time. There was then considerable uncertainty regarding the scale of magnitudes, especially in the southern hemisphere. The comparatively small aperture employed by Bailey made

it difficult to observe the fainter stars. In reproducing these charts and sequences, the A.A.V.S.O. was endeavouring to supply southern observers with at least a uniform set of charts in place of a miscellaneous collection drawn from widely different sources.

Apart from the variables included in Campbell's work, there is no standard source for visual sequences of the southern variables. For the majority of variables south of -30° no charts, let alone sequences, have been published. Many were discovered at Harvard from studies of their plates. Bare details of range, position and class were published. Discoveries made elsewhere were sometimes announced with a chart and, occasionally, with a photographic sequence. In assembling all published data, the one vivid impression is of a bewildering conglomeration of material with no pretence to uniformity.

Whatever knowledge is secured of the variations of most of these stars will be derived from the work of the amateur organizations. That has been freely acknowledged. But the amateur, certainly should be making a scientific observation that conforms to all requirements of accuracy. To do this he should have the raw material of reliable charts and sequences. In general, whilst an amateur organization may print the charts, they depend on others for the data that are incorporated on the chart.

So we are faced with the position that for most of the southern variables suitable charts and sequences have to be produced. For those in Campbell's publication a revision of the sequences is necessary.

It is highly desirable that such sequences should be on an international system of magnitudes. It might be an advantage, in order to appreciate what has to be done, to review the position of southern magnitude systems. In 1893 the C.P.D. was published and has remained the main authority for southern stars until comparatively recent years. In fact some 52 years after the C.P.D. was published it could be stated (Stoy and Cormack, 1945) that a standard magnitude system was non-existent in the Southern Hemisphere.

Since 1938 the Cape Observatory has had an extensive programme whose object is to provide reliable photographic and photovisual magnitudes for all stars south of declination -30° whose positions and proper motions are being determined in the photographic revision of the A.G. Zones. A total of 75,000 stars are involved, mainly between visual magnitudes 7 and 10. Originally standard magnitudes were determined on the 1948 "S" or Southern system for the Harvard *E* regions at declination -45° (Cape, 1948).

It was found that the 1948 system was unsatisfactory, because of a photographic effect analogous to the Purkinje effect in visual photometry.

This position was corrected in the 1953 S system (Cape, 1953a). This provided reliable standard magnitudes in the *E* regions for over 700 stars between magnitudes 2 and 16, though the system was considered reasonably well defined only to magnitude 11. Details of the series of observations on which the 1953 S system rests have been published (Cape, 1953b).

In 1953 a second bright star programme was commenced at the Cape. This includes all stars in the Yale *Catalogue of Bright Stars* between $-4°$ and $-64°$, as well as a number of fainter stars having a large parallax and/or proper motion. The first list of photoelectric magnitudes and colours for 214 stars in this programme was published in 1954 (Stoy, 1954). Since then additional results have appeared frequently in the *Monthly Notes of the Astronomical Society of South Africa*. Tables have also been published for converting these magnitudes and colours to the International system and to the *B,V* system of Johnson and Morgan.

This is not the place to discuss the Cape programme in detail. Sufficient has been stated to show that this work will provide reliable standard magnitudes in the *E* regions at $-45°$ and ultimately in other areas.

Faced with the position outlined, the New Zealand Section has been forced to produce its own charts. These, in general, have plotted on them the stars available for each region from the C.P.D. and Henry Draper Catalogue. Then other stars are added at the telescope. When such charts are completed suitable comparison stars are selected and the variable compared with these. For identification purposes each comparison star is assigned a chart letter.

It can be argued that the purpose behind the observations is to determine the period of each variable and how it varies. Therefore any knowledge of magnitudes of comparison stars can be dispensed with. All that is required, on this argument, is to publish the observations in step values, and to determine, from such observations, a light curve.

This argument is, in the writer's opinion, false. Ultimately it will be necessary to treat all variables statistically in order to classify range against period, spectral type, type of curve against other data and so on. To do this results must first be in magnitudes. They too should be uniform so that the entire material is homogenous. That implies having the magnitudes in the first place on the International Scale. False conclusions can easily be reached by combining material derived from widely different methods.

Minor variations in the light curves of Mira Ceti variables are likely to become of much greater importance than in the past. To discuss these it seems that the results should be in magnitudes rather than step values

which could well vary within wide limits. It is unlikely too that research workers would take kindly to having to transfer step values to magnitudes and the aim of any amateur organization is to provide the observational data in the form that is best handled by investigators.

Under these circumstances the New Zealand Section prefers, when there is no existing sequence, to wait until the magnitudes of the comparison stars are well determined before publishing their results. That is why we keep on record the full details of each observation. An exception has been made to this rule, however, in the case of stars of the U Gem type. Here a preliminary sequence of magnitudes is determined visually using some definite star as zero point and determining the step values of the comparison stars from this. The values of the steps are determined and the results converted into magnitudes before publication.

Work of this nature has been confined to the two most experienced observers, A. F. Jones and the writer. It has been found that their individual step values are in excellent agreement and vary between 0.07 and 0.10 magnitudes, being dependent upon the nature of the background effect. For the Milky Way fields, where the background effect is most noticeable the step has its higher value; for fields with a paucity of stars, its lowest value.

For the U Gem stars the overriding consideration has been to make available charts and comparison stars, so that these variables can be followed constantly, preferably by observers differing widely in longitude. At the same time the main characteristics of such stars are made known in the hope that spectroscopic work will be undertaken. An illustration of what has been done is given by the N.Z. work on VW Hydri (Bateson and Jones, 1956). This variable deserves to rank with the type stars of its class but had been almost entirely neglected.

In the succeeding article an attempt is made to show what steps are being taken to overcome the problem of sequences that confronts the southern variable star observer.

Organization. The N.Z. Section has reached the stage, when, from the administrative viewpoint, it must either form a permanent full time Headquarters on a professional basis, or, it must content itself with making observations and publishing these alone. At the same time it is recognized that there is an increasing need for data on the southern variables. More attention is being directed to the Southern Hemisphere. With additional observatories both proposed and in operation, there will be a greater call for predictions so that spectroscopic and other programmes

can be arranged. Active steps are in hand to make the change in organization that is needed.

Equipment. Photoelectric equipment would be a valuable aid to work in determining reliable sequences. With such equipment it would be possible to use the standards from the Cape and greatly accelerate the programme of producing sequences. The addition of the 16-inch reflector to the writer's own equipment may make this extension of our work possible.

International Co-operation. One necessity, as charts and sequences become available, is to see that all southern observers use the same sequences. It would appear too that the time has come when the interests of variable stars generally can best be fostered by the handling of all records at some central bureau. At present, records are published by a wide number of organizations. A pooling of results would appear to present a material advantage to the professional. In fact, the writer would go so far as to say that an improvement of this nature would be justified in the Northern Hemisphere too. But he has sufficient problems of his own without worrying about theirs!

(To be concluded.)

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A ROMAN SUN-DIAL

By Frederick A. Stebbins
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Descriptions and pictures of the various kinds of portable sun-dials usually include a small compact instrument briefly called a "Roman Dial". There seems to be nothing in print that describes its working principles or analyzes the mathematics on which it is based. It turns out to be surprisingly ingenious in its construction, and it accomplishes something quite different from what is generally supposed. Figure 1 is a photograph of such an instrument in the Evans collection, now in the Museum of the History of Science at Oxford University. It is a bronze disk with a diameter of 60.5 millimetres. It dates from about 250 A.D. At the top is a small ring that was used for attaching a cord, now lost, from which the dial was suspended. The edge of the upper right quadrant is divided into ten-degree intervals, beginning with XXX, 30° in Roman numerals, and ending with LX, 60° in the same notation. The circle just inside the calibrations is the edge of a second smaller disk, countersunk in the first. The smaller disk rotates on a central pivot which also carries a peculiarly shaped object that combines both the gnomon and the actual dial plate. The smaller disk is marked with a diameter largely obscured by the dial plate. On either side of this diameter are short portions of radii at a distance of 23½°. One of these is marked VIIIKIVL, and the other VIIIKIAN, eight days before the kalends of July and January respectively. Those who remember the Roman calendar from their study of Caesar and Cicero will easily translate these dates into June 24 and December 25 in modern notation. They indicate the summer and winter solstices at the time the dial was made. The smaller disk is also marked with a radius at right angles to the diameter. The disk is to be turned so that this radius comes under the figure for the observer's latitude as shown on the outer quadrant. In the photograph, the setting is for about 47° of latitude. On the back of the dial is a table giving latitudes of thirty places from EGYPT XXX in the south to BRIT LV in the north.

Turning to the central object, the gnomon is the perpendicular projection at the left. The dial plate is the long, narrow, surface that begins at the base of the gnomon and curves upward to the right. The hour lines run across this and are not numbered. Five are marked, and the end of the curve makes a sixth. This central object is to be turned

FIG. 1—Roman sun-dial, slightly larger than the original. (Courtesy of the Curator of the Museum of the History of Science, Oxford.)

on the pivot so that it takes its proper place between the solstice lines in accordance with the sun's declination on the date that the dial is used. As nearly as can be read from the photograph, the setting is for either ten days before the vernal, or ten days after the autumnal equinox.

The dial is used as follows: 1. Set the smaller disk for the observer's latitude. 2. Set the gnomon for the date the observation is made. 3. Pick up the dial by the cord and turn it until the shadow of the gnomon lies wholly on the dial plate without falling askew on either side. 4. The end of the shadow of the gnomon gives the hour by its position among the hour lines. Some persons have jumped to the conclusion that the Roman Dial is only the much commoner Universal Ring Dial with the equatorial ring somewhat compressed for ease in carrying. This is too much of a simplification and obscures its true nature. Neither is it an astrolabe, although some astrolabes have such a dial among their accessories.

To turn to its astronomical principles, in figure 2 is a side elevation of the dial plate and gnomon. *AB* is the gnomon, *BC* the edge of the dial plate. The various hour lines are projections of the corner, *A*, onto the dial plate made by rays from the sun 15° apart. The plate is curved, simply so that a shadow at noon, when the ray of sunlight is on the

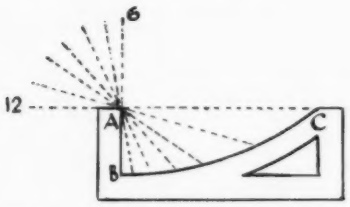

FIG. 2—Side elevation of the dial plate and gnomon.

line 12*AC*, will not be infinitely long. Note that a ray of sunlight during the afternoon will sweep from the line 12*AC*, down the line *CB*, to the line 6*AB* at evening. As *A*, *B*, and *C* lie in a plane, the rays of light have swept over a plane surface. Projecting the rays backward shows that they must intercept the celestial sphere with a plane surface. Point *A* is to be considered as at the centre of the celestial sphere. A plane through the centre of a sphere intercepts the surface on a great circle.

To take an example in middle latitudes, figure 3 shows the visible portion of the celestial sphere with the gnomon at the centre. The

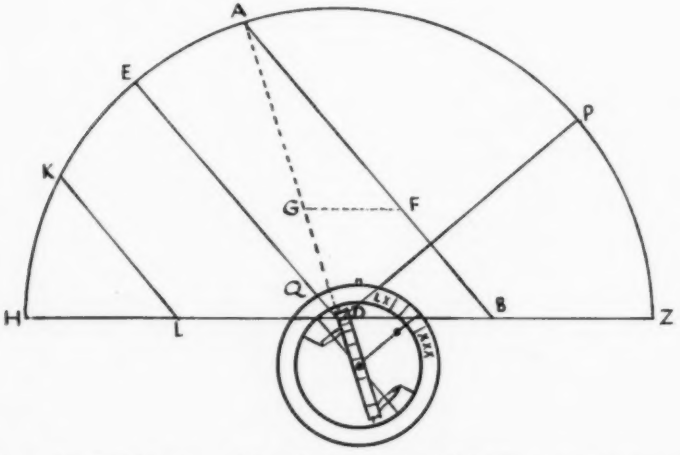

FIG. 3—The visible portion of the celestial sphere with the gnomon at the centre.

latitude is 40° north. *P* is the north celestial pole, *EQ* the celestial equator, *HZ* the horizon. Let the date be the summer solstice and let the hour be sunrise. If the sun's path lay along *D G A*, a great circle seen edgewise,

it would be possible to turn the dial into the plane of the meridian, and for the entire morning the shadow would stay on the dial plate, growing steadily longer, until at noon the plate would be entirely covered. In fact, the sun's path on this date is *B F A*, substantially coincident with the Tropic of Cancer, and is not a great circle. Consequently, at sunrise the gnomon will cast a horizontal shadow unless the dial is twisted out of the meridian by an angle that subtends arc *DB*. When this is done, the gnomon points to the sun and there is no shadow at all. When the sun has risen to point *F*, the dial must depart from the meridian by a smaller angle measured by arc *GF*, and so on until the dial comes into the meridian at noon, with the sun at *A* and the plate entirely covered with shadow. This twisting of the dial causes it to follow the sun as if its path was *D G A*, althought it is in fact *B F A*. As the dial simply measures the sun's altitude, it follows that it can also handle the problem in the afternoon without change of setting, but analysis is more complicated. Suffice it to say that the dial swings much farther out of the meridian, and after a turn of more than 180° points directly to the sun at sunset.

The point to notice is that this dial always reads exactly six hours from noon at sunrise and sunset, even on long days in summer and short ones in winter. It is incorrect to assume that it is hopelessly in error. What we have is not an equal hour dial, such as the Universal Ring, as some have supposed, but one that gives the old "unequal hours"; that is, twelve hours from sunrise to sunset regardless of the length of the day. This form of time division, with long daylight hours in summer and short in winter, seems bizarre today; but when sun-dials were taken seriously, even kings and emperors had to cease most activities at sunset because of poor artificial lighting. Under such conditions it would be more important to know what proportion of the daylight remained than the exact position of the earth in its rotation. Then they were not bothered with withholding and time-and-a-half overtime. Many old sun-dials, fixed and portable, are designed to give a reading in unequal hours, and early astronomers were concerned with the problem of converting one kind of hour into the other. For an example readily accessible, though at a later period, see Chaucer's *Astrolabe*. Part II, propositions 7 through 11, are concerned with this.

If this is an unequal hour dial, it remains to be seen whether or not it gives an accurate reading. In figure 3 the sun's semi-diurnal arc, *B F A*, is substantially more than a quarter circle. At the winter solstice it will be along *KI* and less than a quarter circle by the same amount, but the dial plate is calibrated on the assumption that the semidiurnal

arc is an exact quarter circle. This is true only at the equinoxes. Figure 4 shows the various semidiurnal arcs for 40° arranged for comparison. All are divided according to the unequal hour system. While the divisions do not agree exactly, they are so close that the dial is able to accomplish

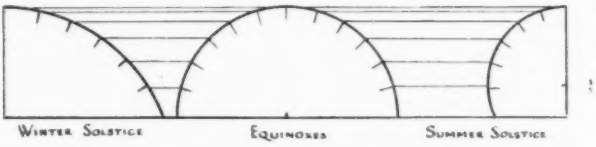

Fig. 4—Semidiurnal arcs for latitude 40°.

its purpose much better than might be supposed. Trigonometric calculations will reveal that in latitude 40° the maximum error is less than fifteen minutes of time. This would be negligible in the age when the dial was made.

Altitude dials, with unequal hours, are fairly common, but few are adaptable to different latitudes, and most of them require the solving of many spherical triangles in their construction. The Roman Dial can be used in many latitudes. Its construction is mathematically simple. It furnishes a highly ingenious solution of a complex mathematical problem and excellently illustrates the geometrical acumen of the early astronomers.

A GREGORIAN TELESCOPE

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A small Gregorian telescope, believed to be among the oldest astronomical instruments preserved in Canadian Museums, aroused widespread interest while on exhibit recently in the University of New Brunswick Library. Modern astronomers, either professional or amateur, seldom encounter this particular design in their scientific pursuits, although the telescope named after Gregory chronologically precedes the other two better known reflectors. A brief historical review of the development of the telescope as the prime instrument in astronomical research, gives one an appreciation of the place which the Gregorian telescope holds in relation to present-day equipment.

Telescope is a term derived from the Greek words τῆλε (far) and σκοπεῖν (to see). Jan Lippershey of Holland is generally credited with inventing the instrument in the year 1608 (King, 1955) but did not use the term telescope to identify his invention. In 1609, Galileo made the first scientific observations with a similar instrument which he constructed and referred to as a "perspicillum". Two years later the poet Demisiani suggested the word "telescope", a term which has not only remained, but in view of modern developments in radio astronomy, has been greatly extended in its meaning.

Refractors pre-dated reflectors by half a century but the early lenses had many optical defects with the result that the image was coloured and of inferior quality. Empirically, attempts were made to eliminate the colour from the image by introducing objectives of longer and longer focal lengths. This approach led to improved but unwieldy instruments.

Newton first outlined the reasons why a single objective lens produced an image showing colouration but an erroneous conclusion on the behaviour of lenses of different refractive powers when combined caused him to predict that no improvement was to be expected in the refractor. His attention thus turned to the reflector and the development of the achromatic doublet lens was left for others to complete.

Proposals for the combination of two-mirror systems were brought forward in turn by James Gregory in 1663, Isaac Newton in 1668 and Guillaume Cassegrain in 1672. The arrangements are as shown below.

It is readily apparent from the diagram why most amateur telescope makers start with the construction of a Newtonian instrument. Casual

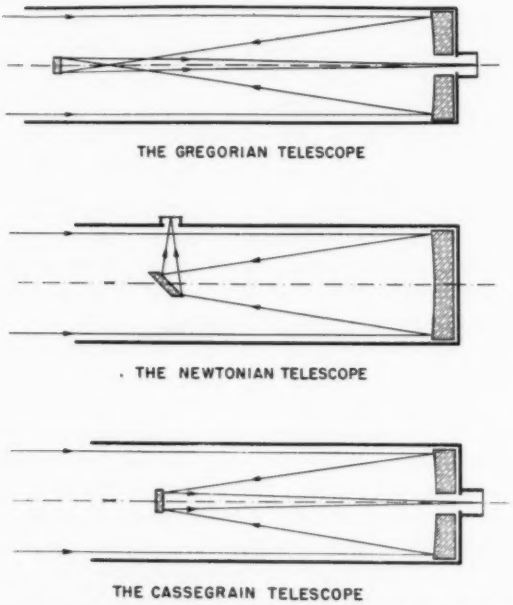

FIG. 1—A composite view of the optical systems for the Gregorian, Newtonian and Cassegrain telescopes; these are the three basic forms of reflectors most frequently used.

examination of the three types reveals that for the Newtonian telescope, the grinding and polishing of a single optical surface is all that is necessary before the final stage of aluminizing or silvering is carried out. The mounting of this and the other component parts is done by a relatively simple and fairly standard method.

The other types of reflectors require the figuring of two optical surfaces with final correction of these in combination. The added complications of centrally drilling the large primary mirror and mounting the secondary one is sufficient to discourage all but the most enthusiastic amateurs from attempting to construct an instrument of either the Gregorian or Cassegrain form.

The largest refracting telescope was constructed in the latter part of the nineteenth century; in the twentieth century the 100-inch and 200-inch reflecting telescopes have been produced as well as radio telescopes up to 250 feet in diameter. The advances in modern optical telescopes have extended, through a narrow viewing gate, the knowledge of our surroundings by increased penetration to regions previously unseen.

Radio techniques are rapidly opening a second gate by which much additional information on the universe will be gathered.

FIG. 2—The Gregorian reflecting telescope, housed in the Archives Section of the Bonar Law-Bennett Library of the University of New Brunswick, Fredericton, N.B. While the age of this telescope is not definitely known, a date prior to 1800 is suggested by comparison with other historical research (King, 1955, figure 68).

In 1955, this Gregorian telescope was transferred to the University of New Brunswick from the York-Sunbury Historical Society through the efforts of Dr. D. J. MacLeod. He had been influential in obtaining custody of it for the Society some years earlier; later, he realized that this holding should more logically be placed in the collection at the Library along with the other astronomical instruments preserved from the Brydone Jack Observatory.

The instrument was brought to Fredericton by the late Professor R. W. B. Pugh, (Professor of Modern Languages in the University of New Brunswick, 1926–1939). On his departure from Fredericton, many of his personal possessions were left with the Babbitt family with whom he had lived for a considerable period of time. These items were never

claimed and with the closing of the Babbitt home (some years after the passing of Professor Pugh), many things of historical interest went directly to the Society.

It was reported verbally that this telescope once belonged to Cecil Rhodes (1853–1902). While this possibility appears reasonable, one can only speculate as to how it came into the possession of Professor Pugh. The Professor was an ardent outdoor man who took an active part in Scouting; this avocation may well have prompted his interest in acquiring the instrument.

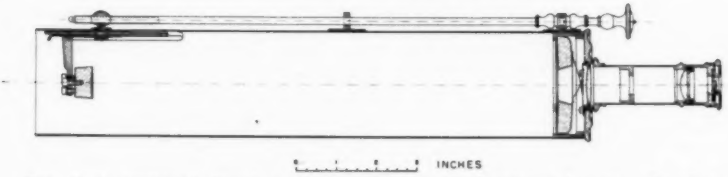

FIG. 3—A sectional drawing of the Gregorian reflecting telescope, showing the optical and mechanical parts of the assembly. The overall magnification of the system is about 21, the f-number approximately 18.

A measure of the skill and careful workmanship that went into this instrument has been captured in the reproductions of figures 2 and 3, although a full appreciation can be obtained only from seeing the original. The craftsman who produced this telescope was not following blueprints nor did he use precision lathes, milling machines or modern presses in its fabrication; and yet he achieved an item that is most worthy of preservation.

At a period in history, when man's mastery of the air is giving way to man's mastery of space, the time is appropriate for surveying the path by which he has arrived at his present level and seeing in part the path which lies ahead. Among the countries of the world, Canada, young in years and in development, is gradually building her own distinctive culture. This is becoming more apparent in our language, our music, our art galleries and our museums. As representatives of the oldest known science, we as astronomers must add to this heritage by preserving for the future the instruments with which a few facts were discovered about our surroundings. When we view a telescope of this early type, all of us should be reminded that the work of Fraunhofer and Dolland led to the Yerkes refractor, while that of Gregory, Newton, Cassegrain and others led directly to the giant of Palomar.

King, Henry C. 1955, *The History of the Telescope*, Charles Griffin & Co. Ltd., London.

CANADIAN SCIENTISTS REPORT-XIII

VARIABLE STARS

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Introduction. One of the principal problems of modern astronomy is the attempt to understand the processes of stellar evolution and to work out the past histories of the stars, galaxies and gas-clouds we see around us. To this end the study of variable stars is thought to be of great importance since it is likely that when a star is undergoing marked secular or irreversible change, it will pass through a period of instability and become a variable star. Hence the numbers of variable stars should throw light on the evolution problem. Furthermore, detailed study of the more violent of the variable stars might lead to some indications of the detailed processes of evolution of stars. In a sense such stars constitute a stellar population which is pathological, and their study is obviously important. This group of stars is studied for many other reasons than their possible importance in a scheme of stellar evolution. Analysis of the physical processes involved in the pulsation of stellar atmospheres contributes greatly to general astrophysical progress, and it was Eddington's attempt to interpret Cepheid variation which led him to develop the whole theory of the internal constitution of the stars. In the following discussion we shall leave out of account those stars whose light is indeed variable but which really constitute an eclipsing system of two stars, the variation of light being caused by the geometrical eclipse of one star by the other. Famous long-known systems such as Algol are of this nature but we exclude these stars from consideration since they are not intrinsic variables.

Designation of Variable Stars. There exist many thousands of stars whose light and radial-velocity changes are not explicable by supposing that the star is either an eclipsing system or is in some sort of orbital motion. The number of known variables increases rapidly and there is a great variety of behaviour among them. Many of these stars change in a very irregular manner, but others show a remarkable similarity between one cycle and the next so that maxima and minima of brightness are pre-

dictable with great accuracy. Periods vary from a few hours to several hundred days. It is clear that very long periods would tend to escape detection and also very short ones, but recent work has shown that there may be fluctations of the order of a few seconds in the light of some variables. On the whole the greatest changes in the light are found in the stars of long period. The standard catalogue of variable stars is called *The General Catalogue of Variable Stars*, the first edition of which was published in Moscow in 1948 and edited by the Russian astronomers, B. V. Kukarkin and P. P. Parenago. The publication of the second edition has recently been announced. The introduction is written in Russian and English and there is no difficulty in consulting this important list since constellation names are given in their Latin designations. The catalogue lists over fourteen thousand variable stars with their names, positions in the sky, magnitudes at maximum and minimum brightnesses, spectral types, their variable-star types, the epochs in Julian days from which the periods are measured, the periods themselves, the light ranges, and references to important publications on the individual stars. It should be pointed out that some 2700 of the stars listed are eclipsing variables with which we are not now concerned. Some of the above-mentioned descriptions require a little explanation. First, as might be expected where many thousands of objects are involved, the naming of variable stars is somewhat haphazard, but in principle the procedure is as follows. When there is sufficient evidence that a star is variable it is given its constellation name preceded by letters denoting the order of discovery. The first variable discovered in a constellation has the letter R (the first variable listed in the catalogue is R Andromedae) and then they receive the letters S, T, . . . , Z. After Z the two letters RR follow, then RS, RT, . . . , RZ, then SS, etc. until ZZ is reached; following this, the letters AA are assigned and so on, until QZ is reached, then the stars are named V335, V336 etc. By 1925 about two and one-half thousand stars had been listed by this method; the number is now five times as great. The most important bibliographies relating to variable stars are the large volumes of the *Geschichte und Literatur des Lichtwechsels der Veranderlichen Sterne* (*History and Literature of the Light curves of Variable Stars*) published by the Potsdam Observatory. The most recent volume, edited by H. Schnellar, was published in 1957, and brings the references to publications on stars known and designated in 1938 up to the year 1954.

Second, we have to consider how the type of variable star is determined; this is not to be confused with the spectral type. There are recognized now approximately twenty-six types of variable stars, ranging from the long-period or classical Cepheids, through the long-period variables to

the hot and very short-period β Canis Majoris stars. Many of these twenty-six subdivisions are named after the most prominent representative of the class such as δ Cephei, prototype of the classical Cepheids, or β Canis Majoris, prototype of the short-period hot stars of spectral type B1. We shall not try to give examples of every type of variable star phenomenon, but will content ourselves with a brief description of the principal classes of stellar variation.

Discovery of variable stars. Most variables are now found by comparison of photographic plates of a star field, in which case several may be found at once, or by photoelectric observation and comparison with standard non-variable stars. Many very faint variables can be found by the first method, variables in fact too faint to be included in the usual catalogues, and whose position can only be indicated on marked photographs. No regular method of nomenclature exists for these faint stars. Inspection of stellar spectrograms also turns up many important variable-star discoveries; some peculiar feature in the spectrum such as the occurrence of bright lines is usually the clue in these cases. Furthermore it is only when the star is bright enough for spectrographic observations to be possible, that anything approaching an adequate study of the star can be made.

Kinds of stellar variability. As stated above we leave out of consideration the eclipsing binaries as not real variables. As evidence of variability we have usually either a light curve, obtained either photographically or photoelectrically or in many cases visually, or a radial-velocity curve obtained from measurement of many stellar spectrograms. It can happen that the star has a changing spectrum as its principal feature, with very little light or radial-velocity variation. Such stars are known as spectrum variables. The main classes of variables can be accounted for if we divide them into regular-period variables and irregular-period variables, though there is not any sharp dividing line between these groups. The regular-period variables include the Cepheid and long-period variables and the β Canis Majoris stars, while in the other class we place the irregular variables and the novae as temporary stars.

Variables with a regular period. The most important and best studied group of such stars is the Cepheid variables. The prototype δ Cephei has a period of nearly a week, but there are many Cepheids with periods of less than a day and these are known as cluster variables since they are found in large numbers in the globular clusters. There are important

differences between these two sorts of Cepheids, and those of longer period are now called classical Cepheids. However these stars have many properties in common which we shall discuss briefly.

The Cepheid variables. The variation of the light of a typical classical Cepheid is shown in figure 1. It is clear that the light variation is con-

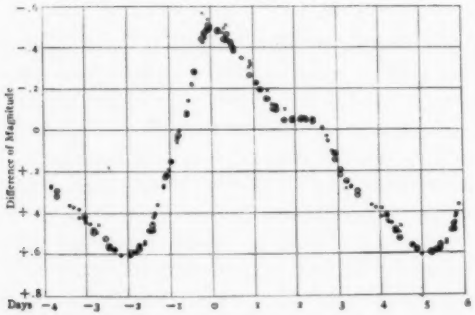

FIG. 1—The light curve of η Aquilae, a typical classical Cepheid.

tinuous. The increase of the light from minimum to maximum is more rapid than the corresponding decrease, an effect that is more pronounced in some stars than others. On the average it is more marked the shorter the period. The light curve remains very nearly identical from cycle to cycle even though minor variations superimposed on the curve sometimes exist. The total range in brightness is about a magnitude, although ranges of 1.5 magnitudes are known. As the light varies the spectrum of these stars changes also. There is a continuous radial-velocity change as shown in figure 2, and also the appearance of the spectrum alters steadily

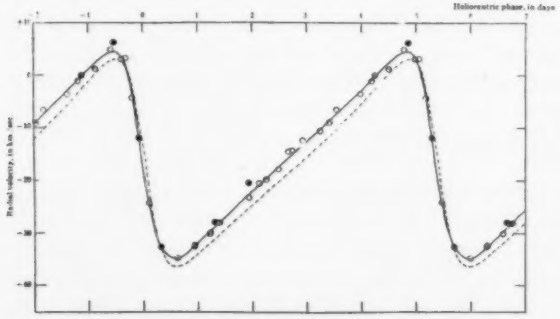

FIG. 2—The radial-velocity curves of δ Cephei.

throughout the period. When the star is brightest the hydrogen lines and certain metallic lines in the spectrum are at their strongest. The two periods derived from the light curve and the radial-velocity curve are equal within the errors of measurement and also the radial-velocity range and the light range are closely proportional. It is seen that when the star is brightest the radial velocity is most negative i.e. the stellar atmosphere has its greatest velocity of approach. An important fact is that the periods are connected with the spectral type in the sense that the cooler the star the larger is the period. One property of the Cepheids has proved of tremendous importance in extending our measurements of stellar distances. For those Cepheids found in large numbers in the Magellanic Clouds, and whose distances are consequently nearly equal, a plot of period against apparent brightness gave a smooth curve. This effect is illustrated in figure 3, where the logarithm of the period is

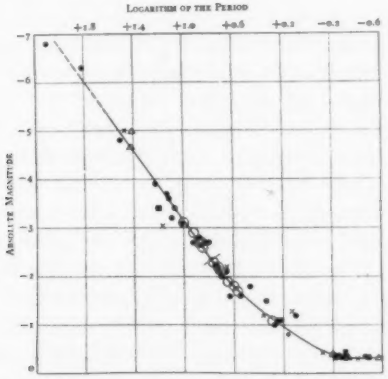

Fig. 3—Period-luminosity relation of Cepheids.

plotted against absolute magnitude. Hence there exists a period-luminosity curve for the Cepheids. To relate the period to intrinsic luminosity and so provide a real measuring-rod proved to be somewhat difficult and large errors at first resulted, but an approximately correct distance calibration by means of Cepheids now exists. By finding the period of a Cepheid in the Andromeda galaxy, for instance, and measuring its apparent magnitude we can find the distance of the galaxy, for from the period we can find the absolute magnitude from the period-luminosity relation, and then the difference between the apparent and absolute magnitudes enables us to find the distance. By such methods it is found that the Andromeda galaxy is one and one-half million light-years distant.

Thus the study of a class of variable stars proved to be of great importance in another problem, the determination of the distances of the extra-galactic nebulae.

Having discussed the similarities of the two types of Cepheids some attention should be paid to their differences. According to present ideas the short-period Cepheids are like the long-period Cepheids in that they are pulsating giant stars, but whereas the long-period Cepheids possess a marked galactic concentration, i.e. are mostly in the plane of the Milky Way, the cluster-type variables (prototype RR Lyrae) do not, but are distributed uniformly in the sky. However the situation is even more involved than this. A certain number of long-period Cepheids also belong to the spherical component of the galaxy, i.e. lie out of the plane of the Milky Way. The form of the period-luminosity curve is similar for both sorts of long-period Cepheids but the two curves have different zero-points. Ignorance of this fact led in the past to many erroneous distance determinations based on an assumed universal period-luminosity relationship. For equal periods, those long-period Cepheids concentrated in the galactic plane are almost two magnitudes brighter than those belonging to the spherical population. A typical representative of the latter group is W Virginis. It is now customary to call long-period Cepheid variables class C variables, and the symbol Cδ is used for those like δ Cephei i.e. possessing galactic-plane concentration, while CW is used for the spherical population (after W Virginis). The cluster-type or short-period Cepheids are given the symbol RR, after RR Lyrae a member of this class; at maximum these stars are almost all of spectral type A, rarely F. The short-period variables may be again subdivided according to the symmetry or otherwise of their light curves, so that RR*a* denotes stars (like RR Lyrae itself) with very asymmetrical light curves in the sense that the ascending branch is very steep. RR*c* is the symbol used to denote short-period variables with almost sinusoidal light curves.

The Cepheid variables do not exhaust the classes of stars whose periods are regular. There remain the RV Tauri stars, the α^2 Canum Venaticorum or spectrum-type variables, and the β Canis Majoris stars. We now deal with these types.

The spectrum variables. These stars show a small variation in light, not more than one-tenth of a magnitude, with periods ranging from about a day to a few weeks. Their principal feature is that the spectrum changes markedly with a period equal to that of the variation in the light. The stars are of spectral type A but their spectra show strong metallic lines of the rare earth elements as well as strontium, chromium and silicon.

It has been found that many of these stars have very strong and variable magnetic fields, presumably connected with their mechanism of pulsation. A star in this class is α^2 Canum Venaticorum.

The RV Tauri stars. The light-curves of these stars have both a principal and a secondary minimum, the depths of which are variable so that the principal minimum can change into a secondary minimum and vice versa. The interval between successive principal minima is regarded as the period and can range from about a month to five months or so; this interval remains sufficiently constant for these stars to be regarded as having a regular period. The range in amplitude of the light reaches three magnitudes. The stars are supergiants with spectral types from G to K, and in any one case the star is hottest at maximum brightness. These stars may be subdivided according to whether the mean brightness remains the same or varies periodically as sometimes happens; the designations are RV*a*, *RVb*, respectively.

The β Canis Majoris stars. These stars are often known as β Cephei-type variables also, and are now donated by the symbol βC. A considerable amount of attention has been devoted to these stars at the Dominion Astrophysical Observatory so that a little more space may be permitted in describing their behaviour than is possible for many of the other stellar classes discussed here.

These stars form a very compact group with spectral types B1-B2, in luminosity classes III-IV, i.e. we are dealing with rather hot giant-like stars. The periods of variation of the radial velocity and light are of the order of three to five hours, so that several cycles of variation may be obtained in one observing session. Unlike the Cepheid variables, whether of long or short period, the epoch of maximum brightness coincides with the phase of maximum compression of the star, considering the radial velocity to correspond to an actual pulsation of the star. Whether these stars, or the other stars with regular periods, are in fact pulsating is not altogether obvious as we shall see later. Some, but not all, β Canis Majoris stars show a double period of variation of light amplitude; when this happens the two periods are close together so that they give rise to long-period ($\sim$ 90-day) beats. The most violent of this group of stars, BW Vulpeculae, does not show this property. This star has a range in velocity of more than 200 km./sec. A typical radial-velocity curve for this star is shown in figure 4, based on spectrograms taken at this Observatory. Inspection of the curve shows that for this cycle the range in velocities is 180 km./sec. and that the curve is *discontinuous*. Large discontinuities occur just before the stationary stillstand phase of the velocity

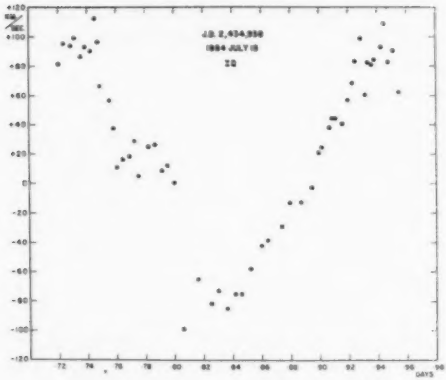

FIG. 4—Radial velocities of BW Vulpeculae.

curve. For example there is a discontinuity of 81 km./sec. preceding the later stillstand and 64 km./sec. following it. Minor disturbances take place during the stillstand and there appears to be quite irregular motion just after stillstand; this corresponds of course to the ejection of matter which would appear to take place somewhat jerkily. It has been shown that there is considerable variation from cycle to cycle in the behaviour of this star in both the amount of discontinuity and duration of stillstand. It should be noted that in order to follow behaviour varying as rapidly as this, high time-resolution is required i.e. exposure-times per spectrogram have to be short. In this case the exposure time was about 3 minutes per plate. An interesting point regarding this star is that the amplitude of the velocity variation is steadily increasing, and at an increasing rate, and so is the period. This would imply that the star is expanding; if this is a real long-term effect and does not reverse itself we shall have found a star in a process of secular change, very important as evidence of stellar evolution. The large velocities of the stellar surface material, since they are much greater than the velocity of sound in the atmosphere of the star, correspond to what are termed shock waves, which are waves of pressure discontinuity analogous to blast waves from explosions. An attempt has been made to explain the observed radial velocities in terms of dissipating shock waves arising from regular disturbances below the stellar atmosphere. If this idea is correct then the ideas of general pulsation, akin to a periodic inflation and deflation of a balloon, would have to be considerably modified. Evidence of radial-velocity discontinuities exists in the case of many other types of variables also. Not all the β Canis Majoris stars have been sufficiently well observed to determine

whether increasing periods and amplitudes occur in all other cases also, but several of the group do possess this property. As for most other classes of variable star, the search for new members is continuing, especially for new members with large amplitude.

Stars with irregular periods. The second large group of stars which are variable consists of those stars whose light or radial velocity varies but without it being possible to assign a definite period. The two classes merge and there exists a class of variables, the so-called long-period variables, whose periods are not altogether definite but which might have been assigned to the class of regular-period variables. The irregular variables include such stars as these and also stars with eruptive properties such as the novae. To begin with the most regular, so to speak, of the irregular variables let us examine the long-period variables.

Long-period variables. Stars in this group are quite numerous and have periods ranging from 50 days to more than 2 years, but most periods lie in the range of 250 to 400 days. The variation in light is large, often as much as ten magnitudes and nearly always more than two and a half magnitudes. The large light range and the consequent faintness of these stars at minimum light give rise to great difficulty in observation, especially difficult is adequate spectrographic coverage over this phase of variation. Often the stars are not observed at all at minimum light so that the light range is uncertain. The symbol M is attached to such stars, after the prototype star of this class, Mira Ceti (*o* Ceti). One of the few stars of this class which has been moderately well observed is R Hydrae and in figure 5 the velocity curve is shown, as given by Merrill (1956).

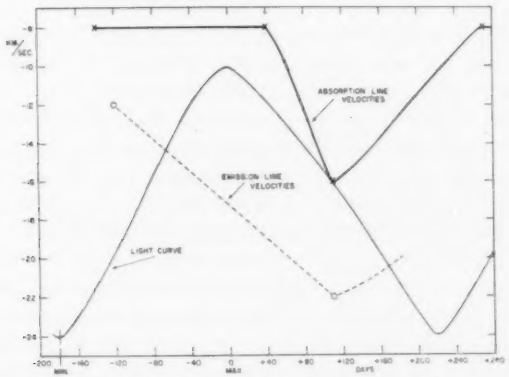

FIG. 5—Radial-velocity and light curves of the long-period variable R Hydrae.

Emission lines are characteristic of this group of variables in certain phases of their variation cycle and the velocities derived from the emission lines are shown. Also the light curve has been shown, on an arbitrary scale for convenience. It is seen that maximum light occurs during the stationary phase of the radial-velocity curve derived from the absorption lines. Although the ejection of material is much less violent than in the case of some β Canis Majoris stars it has proved possible to explain the velocity curve in a similar way, namely by considering the decay of a— in this case— weak shock wave in a very tenuous and cool atmosphere. If we suppose that —8 km./sec. is the velocity of the star as a whole, then the ejected material merely comes to rest and is not observed to fall back into the star. This may be due to the extremely low value of gravity in the atmospheres of these stars, which are certainly very tenuous and of extremely large diameter.

For the class as a whole the light variation is only approximately periodic so that the times of maxima cannot be predicted exactly. Also there are very considerable variations from one cycle to the next in the form of the light curve. Because of the large light variation o Ceti (called Mira, the wonderful) was the first variable star to be recognized (by Fabricius in 1596). At its brightest this star sometimes reaches the second magnitude and is then very conspicuous in its region of the sky; however at minimum it is completely invisible to the naked eye, having magnitude nine at that phase. The long-period variables are often of spectral type M, but spectral types N, R, and S also appear.

The semi-regular variables. There exists also a class of stars called semi-regular variables, which is made up of stars like the long-period variables, having their giant character but with a less pronounced periodicity in their light variation. The range of periods is similar to that of the long-period variables but the forms of the light curves are very diverse, although usually the light range is only from one to two magnitudes, much less than for the long-period variables. The symbol SR is given to this class of variable star. As might be imagined there is no sharp line of demarcation between the long-period variables and the semi-regular variables. Also the latter class shades off into the class of irregular variables to which no periodicity at all can be assigned.

Eruptive variable stars. This very interesting and spectacular group of stars provides us with one of the most important classes of variable star. The term nova or new star was given to stars which flared up suddenly and appeared to come from nowhere. However, temporary star is a more accurate appellation since many novae have been found to be due to the

flaring of previously faint stars, and presumably all have this property. Some novae are the brightest stars ever recorded. In November 1572 a nova (Tycho's star) appeared which was brighter than Venus for several days and was visible during the day! However over a year later this star was invisible to the eye. In 1604 Kepler observed a nova brighter for some weeks than Jupiter, which remained visible for a few years. In recent time the brightest nova was Nova Aquilae which in 1918 increased in brightness from magnitude 11 to magnitude —1.1, almost as bright as Sirius. Novae visible to the eye have appeared about every five years during this century. Since previous photographs of these stars often existed the light curve is known in some cases. It appears that the rise to maximum light takes place in only a day or two; on reaching maximum the star begins to fade almost at once, rapidly at first then more slowly with small oscillations in brightness often taking place, the oscillations often having a very short period. After this a slow return to the original magnitude takes place in many years. Novae are known which have recurred. For instance the star T Pyxidis became a nova in 1890, 1902 and 1920, rising from the fourteenth to the eighth magnitude on each occasion. The novae are hot dwarf stars in their normal state, but when near their maximum brightness they usually show an absorption-line spectrum similar to that of A- or F-type giants. Just after maximum very wide emission bands of hydrogen, helium and other elements occur in their spectra, along with absorption components, often corresponding to enormous velocities of ejection. During the course of the decline in light, bright and forbidden spectral lines, of the sort characteristic of the very diffuse gaseous nebulae, appear. Ultimately the spectra become almost completely continuous or similar to Wolf-Rayet spectra. The symbol N is given to novae, and the class is subdivided according to the speed of change of the light, the symbol N*a* being used for rapidly developing novae, N*b* for slowly developing novae, N*c* for very slowly developing novae. The symbol N*d* is used for recurrent novae like T Pyxidis and T Coronae Borealis.

Stars with even more violent outbursts than the novae are known. The so-called supernovae have novae-like properties but the increase in brightness may be 20 magnitudes or more; in our own galaxy such objects are rare but it is thought that the Crab nebula is the remnant of a supernova outburst observed in China in the eleventh century. There are also several other classes of stars of somewhat eruptive nature but much less violent than novae. We can make only passing reference to these groups which are: (1) R Coronae Borealis-type variables, showing slow non-periodic decreases in brightness of various amplitudes and durations, symbol RCB; (2) RW Aurigae-type stars, showing irregular but rapid light variations,

symbol RW; (3) U Geminorum (or SS Cygni) -type variables which usually show small light variations but occasionally flare in an irregular manner, symbol UG; (4) UV Ceti-type stars, which are cool dwarf stars showing erratic flares, sometimes of large amplitude, symbol UV; (5) Z Camelopardalis-type variables, which resemble U Geminorum variables but have fairly long periods of constant light.

Further work will no doubt increase the classes of subdivision. As a short summary of the above rather numerous variable star types we give in Table I the distribution of the variable stars in the various subdivisions, taken from B. V. Kukarkin (1958). It might be noted also that 2763 eclipsing variables are already known.

TABLE I

DISTRIBUTION OF VARIABLE STARS

Type Symbol	Name	Number
	Regular Variables	
C	Long-period Cepheids	610
RR	Short-period Cepheids of RR Lyrae-type	2426
βC	β Canis Majoris stars	11
α CV	α^2 Canum Venaticorum-type stars	9
RV	RV Tauri-type stars	92
	Total	3148
	Irregular Variables	
M	Long-period variables of Mira Ceti-type	3657
SR	Semi-regular variables	1675
I	Irregular variables	1370
N	Novae	146
SN	Super-novae	7
RCB	R Coronae Borealis-type stars	39
RW	RW Aurigae-type stars	590
UG	U Geminorum-type stars	112
UV	UV Ceti-type stars	15
Z	Z Camelopardalis-type stars	15
	Total	7626

The cause of stellar variation. It is not expected that one explanation will suffice for stars as different as supernovae and long-period variables. Supposing that the eruptive variable stars are in a separate class, we still have a wide variety of behaviour which is somewhat vaguely regarded as vibrational. No satisfactory account of such behaviour is available at present, but it is hoped to give a general account of the leading theories and suggestions in a subsequent article.

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VARIABLE STAR NOTES

By Margaret W. Mayall

The American Association of Variable Star Observers, Cambridge, Mass.

(*These notes were written aboard ship, between 60° and 71° North Latitude.*)

The Xth General Assembly of the International Astronomical Union was held in Moscow, August 11–20, 1958, at the invitation of the Academy of Sciences of the U.S.S.R. About 1,000 astronomers and their families gathered from all around the world for a memorable meeting.

The highlight of the meeting, in the eyes of astronomers interested in variable stars, was the presentation of copies of the Second Edition of the *General Catalogue of Variable Stars*, by B. V. Kukarkin, P. P. Parenago, Yu. I. Efremov, and P. N. Kholopov. The printing was completed just in time for the meeting of the Variable Star Commission. The catalogue is published by the Academy of Sciences of the U.S.S.R., Moscow, and is distributed free of charge to astronomers throughout the world.

The first edition of the catalogue was published in 1948, and Supplements were issued each year, until there were nine in all. This second edition contains information on 14,708 variable stars which were assigned their permanent names or designations before 1958. The scope of the second edition is greatly expanded over the first, making it necessary to print it in two volumes.

The first volume contains the main table of the catalogue, in which all fundamental data for the variables are given. The variables are listed by constellations, which are arranged in alphabetical order of their Latin names. The Russian names of the constellations and the adopted 3-letter abbreviations are also given at the tops of the pages.

The main table is divided into 17 columns, spread over two pages of the volume. The left hand page contains all data concerning co-ordinates and bibliographic references, and the right hand page the data concerning the physical characteristics of the variables.

On the left hand page of the main table we find the name of the star; co-ordinates for 1900; precession for the equinox of 1900; galactic co-ordinates; and bibliographic references to the most reliable investigations of light variation and to identification charts, if they have been published. If no chart has been published, and the variable is listed in one of the Durchmusterungs, that number is given.

On the right hand page, the name of the variable is repeated, followed by the symbol for the type of variation, divided into three general classes of variation: pulsating, eruptive and eclipsing.

Under the *pulsating variables* we find the following types:

C—long period or classical Cepheids, with periods from 1 to 50 or 70 days. When possible, they are subdivided into types Cδ—variables with small radial velocities relative to the sun, and belonging to the flat component of the galaxy; and CW—large radial velocities and peculiar light curves, belonging to the spherical component of the galaxy.

I–irregular variables, subdivided according to spectral types into *Ia*–early spectral classes; *Ib*–slowly varying irregular variables, giants, of late spectral classes (K, M, C, and S); and *Ic*–irregular supergiants of late spectral classes.

M–Mira Ceti type variables, giant stars with amplitudes over 2.5 magnitudes, periods from 80 to 1,000 days, and emission spectra of late type (Me, Ce, and Se).

SR–semi-regular variables; giant or supergiant stars with noticeable periodicity in the range of about 30 to 1,000 days, frequently disturbed or interrupted, and with small amplitudes. They are subdivided into types *SRa*–giants of late spectral classes (M, C, S), comparative stability of period and small amplitude; *SRb*–giants of late spectral classes (M, C, and S), but unstable periodicity, often constant at times; *SRc*–supergiants of late spectral classes; and *SRd*–semi-regular giants or supergiants of spectral classes F, G, and K.

RR–short period Cepheids or RR Lyrae stars, giants of spectral class A, periods ranging from $0^d.05$ to $1^d.2$, and amplitudes not exceeding 1 to 2 magnitudes. They are subdivided into types *RRa*–variables with very asymmetrical light curves, much steeper ascending branch than descending; and *RRc*–variables with almost symmetrical curves, often sinusoidal, and with a mean period of $0^d.3$.

RV–RV Tauri type variables, supergiants with comparatively stable periodicity; a double light curve consisting of alternating main and secondary minima of variable depth; intervals between 2 successive main minima ranging from 30 to 150 days; and spectral classes ranging from G to late K. They are subdivided into *RVa*–constant mean brightness; and *RVb*–with periodically varying mean brightness.

βC–pulsating giants with periods from $0^d.1$ to $0^d.3$, amplitude about 0.1 magnitude, and spectral classes B1 to B3.

δSc–pulsating variables with amplitudes less than 0.25 magnitude, periods less than 1 day, and of spectral type F.

αCV–variables with periods between 1 and 25 days, amplitude less than 0.1 magnitude, and of spectral type Ap, with lines of metals and rare earths, and many of the stars possessing powerful variable magnetic fields.

The *eruptive variables* are classified as:

N–novae, variables with explosive increase of brightness of from 7 to 16 magnitudes. They are subdivided as follows: *Na*–typical novae characterized by a rapid increase of brightness followed by a decrease of 3 magnitudes in 100 or less days; *Nb*–typical novae with a decrease of 3 magnitudes in 150 or more days; *Nc*–novae with particularly slow development, often remaining near maximum brightness for many years; *Nd*–recurrent novae, with 2 and more flares recorded; and *Ne*–nova-like variables, a heterogeneous class with light variations or spectral characteristics similar to the novae, but probably bearing no real relationship to them.

SN–supernovae, stars that suddenly increase their brightness for 20 or more magnitudes, and then decrease slowly.

RCB–R Coronae Borealis type variables, high luminosity stars of spectral classes F to K and R, characterized by slow non-periodic drops in brightness from 1 to 9 magnitudes, and of different durations.

RW–irregular variables of the main sequence, or subgiant spectral classes B to M, characterized by irregular, very rapid light variations. The majority of them are associated with bright or dark diffuse nebulosity.

UG–U Geminorum or SS Cygni type variables: dwarf stars showing small light fluctuations, with rapid outbursts of from 2 to 6 magnitudes. The mean intervals between outbursts are from 20 to 600 days.

UV–dwarf stars of spectral types dM3e to dM6e, characterized by rare flares with amplitudes from 1 to 6 magnitudes, and duration of a few minutes.

Z–Z Camelopardalis type variables, similar to the U Geminorum type but with the cyclic variation interrupted by long periods of constancy. Amplitudes are from 2 to 5 magnitudes.

The *eclipsing binaries* are classed as type *E*, with subdivisions *EA*, *EB*, *EW*, and *Ell*, according to the standard types of binary systems.

Other symbols used are an *asterisk* for unique variables which cannot be classed in any of the above types; *cst*–stars of constant brightness, which were suspected of variability and given names, but subsequent observations proved they were not variable; and *?*–unstudied variables. The authors of the catalogue make an appeal for observers to try to eliminate the question marks from future editions.

Other columns on the right hand page of the catalogue give the *maximum* and *minimum magnitudes* (usually the brightest and faintest ever published); the kind of magnitude, indicated thus: *p*–photographic; *v*–visual, *r*–red, *i*–infrared; the *Epoch* expressed in Julian days; *period*; *M-m*, time of brightness increase for physical variables, and *D*, time of eclipse duration for binaries, in hundredths of the period; and, in the last column, the *spectral type*.

The first volume of the catalogue ends with valuable notes on the peculiarities of many of the variables, and bibliographic references. The notes are in Russian, but it is hoped that the International Astronomical Union will authorize their translation and publication in English.

(To be concluded.)

A.A.V.S.O. Nova Search Report (From George Diedrich, Chairman):

Observations of Nova Search Areas were made by the following 12 observers for a total of 164 area-nights. Each name is followed by the number of observations made in June and then July, 1958: Robert M. Adams–3, 3; Richard Bates–21, 3; James Breckinridge–12, 4; Frank DeKinder–3, 8; DeLorne Diedrich–2, 12; George Diedrich–12, 12; Geoffrey Gaherty, Jr.–12, 7; John Morrison–10, 8; Beaufort S. Ragland–10, 5; James F. Wesling–6, 4; I. K. Williamson–1, 4; Katherine Zorgo–2, 0

It finally happened–a nova was found by an A.A.V.S.O. observer–but it was our old friend, the variable star RS Ophiuchi (174406) that brightened once more to *really* earn the title of "recurring nova." Now let's find a real "first-handed" nova. If you have any friends who want to join in our inexpensive pastime, have them drop the chairman a card. Remember to send *your* card to us every month.

Observations received during July and August 1958. A total of 8,463 observations was received: 3,626 from 71 observers in July, and 4,837 from 77 observers in August.

Observer	July		August		Observer	July		August	
	Var.	Ests.	Var.	Ests.		Var.	Ests.	Var.	Ests.
Adams, R. M.	81	153	75	192	Maran, S. P.	8	8	..	..
Allin, R.	30	185	40	274	McGovern, R.	..	..	4	4
Anderson, C. E.	96	138	234	725	McPherson, C. A.	8	8	38	40
Anderson, E.	11	19	3	3	Miller, R. W.	15	33	6	10
Ball, A. R.	10	10	13	13	Montague, A. C.	18	30	14	16
Beidler, H. B.	13	13	13	17	Morgan, F. P.	..	..	5	5
Bicknell, R. H.	20	116	..	..	Nestler, J.	1	1	..	..
Bieda, S. W.	1	6	4	18	Oravec, E. G.	111	217	156	299
Bohannon, B.	2	3	1	1	*Overbeek, M. D.	72	199	65	130
Breckinridge, J.	21	62	15	27	Parker, P. O.	48	48	27	44
Buckstaff, R. N.	..	..	5	9	Pearcy, R. E.	3	3	5	6
Carlisle, J. H.	1	2	2	4	Pearlmutter, A. E.	20	20	30	64
Carpenter, C. B.	24	24	30	30	Peltier, L. C.	19	85	20	117
Charles, D. F.	..	..	5	12	Peters, P.	10	10	27	30
Conklin, J. H.	..	..	1	1	Poynor, G.	..	..	3	3
Cragg, T. A.	175	182	259	284	Price, F.	14	25	..	..
Cunningham, R.	1	1	..	..	Quester, W.	5	16	6	24
Darsenius, G.	1	1	4	4	Renner, C. J.	137	166	110	113
Del Grande, D.	..	..	1	1	Reynolds, F. H.	1	1	..	..
Diedrich, DeL.	2	3	4	7	Rizzo, P. V.	19	25	22	33
Diedrich, G.	2	5	4	16	Robinson, J. C.	19	31	5	5
Engelkemeir, D.	6	13	7	19	Robinson, L. J.	1	1	9	21
Erpenstein, O. M.	..	..	7	7	Roderick, T.	1	1	..	..
Fernald, C. F.	160	318	162	345	Rosebrugh, D. W.	10	85	11	83
Fletcher, D. M.	..	..	4	7	Rosenfield, C. C.	7	9	24	43
Ford, C. B.	140	147	173	187	Rosenfield, D. A.	..	..	2	2
Fuller, K.	14	18	16	30	Rudolph, R.	22	61	37	141
Garland, G.	6	33	4	5	Schrader, M. I.	1	3	..	..
Gemberling, R. H.	49	81	..	..	Schultz, G. W.	4	4	5	6
Godfrey, N. B.	10	11	23	23	Segers, C. L.	31	98	19	47
Goodsell, J. G.	5	5	4	4	Seldon, P.	..	..	15	29
Halvorson, D. O.	12	14	6	11	Sharpless, A. P.	6	6	15	18
Hamilton, R. W.	..	..	1	3	Shea, W. S.	1	1	..	..
Hartmann, F.	131	144	138	146	Silveira, W. M.	3	4	3	5
Hein, G. J.	..	..	2	9	Skaritka, P.	..	..	21	27
Ibanez, A.	..	..	1	3	Smits, P.	15	37	21	59
Judd, D.	1	1	2	2	Solomon, L. H.	14	15	4	5
Kelly, F. J.	11	12	11	11	Taboada, D.	44	44	35	46
Kimball, M.	20	20	..	..	Thomas, H. D.	..	..	8	9
Knowles, J. H.	..	..	17	28	Thomas, M. A.	..	..	1	15
de Kock, R. P.	125	340	141	497	Thurn, V. W.	11	12	..	..
Koons, L. D.	..	..	2	8	Tsai, C. H.	..	..	29	47
Kubanoff, J. H.	1	2	2	4	Valdez, M.	10	13	8	12
Lacchini, G. B.	28	45	64	170	Wend, R. E.	5	7	..	..
Lowder, W. M.	35	49	19	34	Wilson, C. F.	54	106	67	88
Magruder, R. S.	10	17	..	..					

*$3^h\ 30^m$ UV Cet

METEOR NEWS

By Peter M. Millman
National Research Council, Ottawa

PHOTOGRAPHIC METEOR SPECTRA (Appendix 6)

In this appendix I am bringing up to date the listing of photographic meteor spectra and of the publications dealing with this subject. The form of the table follows that used in previous years (see the JOURNAL, vol. 46, p. 121, 1952; vol. 47, p. 217, 1953; vol. 48, p. 225, 1954; vol. 49, p. 169, 1955; vol. 50, p. 181, 1956; and vol. 51, p. 351, 1957). Appendix 6 lists spectra up to the end of 1957. Recent spectra from the U.S.S.R. have not been included as I have not yet secured complete information concerning these. They will be covered in the next appendix.

During 1957 routine meteor photography was carried out, as in previous years, at the Meanook and Newbrook Observatories in Alberta by A. A. Griffin, J. M. Grant, D. Corness, T. E. Chmilar and V. N. Beck, under the direction of Dr. Ian Halliday of the Dominion Observatory in Ottawa. The Springhill Meteor Observatory of the National Research Council, Ottawa commenced operation in July of 1957. Meteor spectroscopy here is a joint programme of the N.R.C. and the Dominion Observatory. Those taking part in the photography at Springhill included Dr. Ian Halliday, Prof. A. C. Ghosh, F. R. Park and the writer. In England W. B. Ridley photographed a fine spectrum in October 1957.

One of the most interesting developments during the past year was the identification by Halliday of the auroral green line of oxygen in several of the meteor spectra taken at the observatories in Alberta (see reference 42). When I was in Moscow recently for the 10th General Assembly of the International Astronomical Union, Dr. I. S. Astapovich gave me a colour print of a meteor spectrum taken on colour film in October 1955, at Ashkabad. I believe this represents the first time a meteor spectrum had been secured on colour film, but I understand there are now several other examples from the U.S.S.R.

I would appreciate being informed of any additional meteor spectra which have not yet been included in this listing.

LIST OF PHOTOGRAPHIC METEOR SPECTRA (APPENDIX 6)

No.	Date			U.T.			Shower	Location (observatory)	Ref.
	y	m	d	h	m	s			
215	1957	4	22	9	12	24	Y	Meanook, Alta. (D.O.)	42
216		6	28	3	45	07		Metcalfe Rd., Ont. (N.R.C.–D.O.)	
217		8	8	6	30	*		Newbrook, Alta. (D.O.)	41
218		8	8	7	12	*		" " "	
219		8	8	10	02	*		" " "	
220		8	8	10	07	*	P	Meanook, Alta. (D.O.)	
221		8	12	7	16	39	P	Springhill, Ont. (N.R.C.–D.O.)	
222		8	12	7	19	50	P	" " "	
223		8	12	8	40	41	P	" " "	
224		8	14	8	58	37		Newbrook, Alta. (D.O.)	
225		8	23	5	21	*		Meanook, Alta. (D.O.)	
226		8	23	9	37	*		" " "	
227		10	22	10	11	30	T	Barnes, S.W. 13 (W. B. Ridley)	
228		11	21	10	54	*		Newbrook, Alta. (D.O.)	
229		12	13	1	39	*	G	Springhill, Ont. (N.R.C.–D.O.)	
230		12	13	2	01	03	G	" " "	

Abbreviations:

G Geminid
P Perseid
T Taurid
Y Lyrid

D.O. Dominion Observatory
N.R.C. National Research Council

* Indicates middle of exposure.

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37. Katachev, L. A. *"Photographic Methods in Meteoric Astronomy"*, chapter 6, Moscow, 1957 (Spectrum 53).
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39. Russell, J. A. *Pub. Ast. Soc. Pacific*, vol. 69, p. 436, 1957 (Spectra 54, 99).
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NOTES FROM OBSERVATORIES

Dominion Observatory, Ottawa

Positional Astronomy. The normal quota of observations was maintained, employing the Meridian Circle, the Photographic Zenith Telescope, the broken type Cooke Transit and the Markowitz Moon Camera. The design and assembly of component parts of the Mirror Transit telescope are progressing. A major rearrangement of electronic components in the Time room was made, and the use of transistors in compact amplifiers pursued.

Stellar Physics. Meteor observations during the Perseid shower were very gratifying. Photographically, several good spectra were obtained at Meanook and Newbrook Observatories; visually, the highest count for a single Perseid night was recorded on August 11/12, when 859 meteors were seen. The new apochromat for the 15-inch refractor has arrived and the test of its performance is keenly awaited.

Geomagnetism. An airborne magnetometer survey of British Columbia and Pacific Ocean areas is in progress. Ground magnetic survey parties are operating in Alberta, British Columbia, Yukon and the Northwest Territories, and to date 18 stations have been occupied. I.G.Y. stations at Victoria, Yellowknife and Churchill were visited and the magnetic observatories at Baker Lake and Resolute Bay were inspected. Good progress has been made in the preparation of the 1960 isomagnetic maps.

Gravity. A major regional gravity survey has been carried out in Northern Quebec along the east side of Hudson and James Bays, with a total of 1,000 gravity stations established. This is twice the normal station density for surveys in Northern Canada and will provide for much better information for reconnaissance geological work. The co-operative programme with the oil companies in Western Canada continued this year. Data for

6,300 gravity stations have now been provided by the companies. During the past field season 700 of these stations were tied to the Observatory network by gravimeter. Additional control for the oil company gravity data is provided by pendulum measurements with the new apparatus. Reduction of these data is in progress and eventually 8-mile maps of most of Western Canada will be published.

Seismology. Tests of short-period seismographs at Resolute have been completed and a three-component set of Willmore instruments is now being installed. Ten temporary seismograph stations were established in British Columbia to record Ripple Rock blast. The seismic profile extended from Victoria through Banff and included the permanent stations of the Western Section. It was further augmented by additional stations operated in Alberta through the co-operation of various oil companies. The blast was well recorded as far east as Banff and less clearly in the Prairies. The travel times of the seismic wave through the earth's mantle to stations in the mountains were about one second longer than those for comparable distances in the Canadian Shield, thus strongly suggesting

Personnel. Dr. J. L. Locke and Mr. M. M. Thomson attended the I.A.U. meetings in Moscow and both visited a number of scientific centres en route. Dr. J. H. Hodgson has been elected First Vice-President of the Seismological Society of America. He is presently studying the mechanism of earthquake origins, as revealed by seismic records, at the Institut de Physique du Globe in France. Visiting scientists with the Division of Geomagnetism have recently included Mr. Mohammad Alauddin, M.Sc., Columbo Plan Fellow from Pakistan, Dr. P. N. Mayaud, Expéditions Polaires Françaises, Paris, and Miss V. R. S. Hutton, Professor of Physics at University College, Achimota, Ghana, who discussed problems connected with Earth Currents. Dr. E. R. Niblett, who obtained his Ph.D. from Cambridge University this spring, presented a paper dealing with Earth Currents at the 9th Alaskan Science Conference at College, Alaska, in September. Dr. W. G. B. Britton who developed a wide-band seismic amplifier during the tenure of his post-doctorate fellowship here, is returning to Wales. Other departures from the staff are Dr. S. C. Das of India, Dr. L. D. G. Thompson and Dr. R. L. G. Gilbert. Mr. J. D. H. Gauthier retired in July after more than 40 years in the Government service. Mr. P. J. Winter and Mr. H. D. Valliant have joined the Gravity Division, Mr. A. M. Bancroft has transferred to Seismology and Mr. R. A. Costanzo has joined the Division of Positional Astronomy.

MIRIAM S. BURLAND

HUME CRONYN MEMORIAL OBSERVATORY, LONDON, ONTARIO

During 1956 and 1957 several items of equipment were added to the facilities of the Observatory. A Bausch and Lomb stereomicroscope for the examination of plates and films requires no further description. A Gaertner Linear Comparator for the measurement of spectroscopic plates has been obtained. It is fitted for either direct viewing of the plate through an eyepiece or for projection of the image on a screen. This instrument is being used for the measurement of plates obtained from other observatories and for laboratory spectra. Plates of H.D. 174369 are being measured and Mrs. Wehlau is measuring plates of ι Orionis.

An iris diaphragm photometer has recently been added. This instrument has been described by Becker and Biber (*Zeitschrift für Astrophysik*, vol. 41, p. 52, 1956). The mechanical and optical parts were constructed at the Astronomische-Meteorologische Anstalt of the University of Basel through the kindness of Dr. W. Becker. The electronics were constructed by Dr. C. Biber. Final adjustment of this instrument is being carried out at present.

A photoelectric photometer for use with the ten-inch refractor has been constructed. The optical column is similar to those built by Kron. A standard light source, diaphragm slide, diagonal mirror and eyepiece, filter slide, Fabry lens and 1P21 photomultiplier form the components. The amplifier and power supply are based on a circuit by Johnson giving four coarse sensitivity steps of 2.5 mag. and seven fine steps of about 0.4 mag. The output is fed into a Brown recorder. An electronic power supply is used to provide the high voltage for the photomultiplier. The assistance and advice of members of the staff of the David Dunlap Observatory on this and other problems is gratefully acknowledged.

A short series of photoelectric observations of Comet Arend-Roland was made during May 1957. A discussion of the performance of the photometer and the results of the observations will appear elsewhere. Observations of a number of peculiar A stars, with known or suspected magnetic fields are in progress to detect and study light variability.

The slow motions of the ten-inch refractor have been changed and minor modifications have been made to the drive. The film holder and

Elementary courses in astronomy and advanced courses for students support system of the eight-inch Schmidt telescope are being rebuilt. in related fields are being given. The emphasis in the advanced courses is on the applications of other branches of science to astronomical problems. A series of Public Night Programmes is held once a month.

Visitors to the Observatory have included C. S. Beals, G. P. Kuiper, D. B. McLaughlin, J. B. Oke, J. Stock, and J. P. Wild.

Financial support for most of the work outlined above has been provided by the National Research Council.

WILLIAM WEHLAU

NOTES

Obituary: Edward Hunter Gowan

Dr. E. H. Gowan, Professor of Physics at the University of Alberta, died on August 27th, 1958, at the age of 57, after a long illness. Dr. Gowan took his B.A. and B.Sc. degrees at Alberta, and went to Oxford as a Rhodes Scholar, obtaining the Ph.D. degree in 1928. He joined the staff of the University of Alberta in 1929 and continued there until his death, becoming a full Professor in 1957.

A charter member of the Edmonton Centre, which was founded in 1932, he served as its President in 1935 and as its Secretary from 1940 to 1957. Dr. Gowan presented many excellent papers at the regular meetings, usually illustrated by well-contrived experiments, and took a great interest in all the doings of the Society.

He carried out extensive investigations on the distribution of ozone in the upper atmosphere, the temperature of the stratosphere and the biological properties of ultraviolet radiation. His achievements were recognized by his election as Fellow of the Royal Meteorological Society.

Dr. Gowan is survived by his wife, Elsie Park Gowan and by their adopted son Garry.

Obituary: George Harper Hall

It is with deep sorrow that the Montreal Centre records the death of George Harper Hall on September 30, 1958. A tragic accident caused his death but a few days after his return from a summer in Europe.

Mr. Hall was born in Scotland and came to Canada in 1911. He was in the Mechanical Engineering Department of the C.P.R. until retirement.

Mr. Hall joined the Society in 1928, and was the Centre's President in 1932 and 1933. He served on the council in various capacities until 1947 when he was elected Honorary President, an office he held until his death. As representative of the Montreal Centre Mr. Hall took an active part in the work of the National Council.

Of wide interests, he was one of the Board of Directors of the Province of Quebec Society for the Protection of Birds. He was active in church affairs, and for fifty-seven years was an elder of the church. He was also an accomplished photographer.

He was highly esteemed among his many friends and associates and will be remembered for his kindliness and for his many services.

E. E. Bridgen

REVIEW OF PUBLICATIONS

Theoretical Astrophysics edited by V. A. Ambartsumyan. Pages x plus 654; 9 × 6 in. New York and London, Pergamon Press Inc., 1958. Price $22.50.

This book is a translation by J. B. Sykes of a basic Russian graduate-level textbook in theoretical astrophysics. The work is in nine parts; the first three deal with stellar atmospheres; part IV with planetary nebulae; part V, novae; part VI, emission line stars; part VII, internal structure of stars; part VIII, scattering in planetary atmospheres and part IX, with interstellar material. The authors are prominent Soviet astrophysicists and the complete volume is edited by the most eminent of them, V. A. Ambartsumyan. The Russian edition of this text was published in 1952 but the text has been revised to make essential changes resulting from research done up to 1956.

The standard of the work is similar to that of the western textbooks at the beginning graduate level. It is particularly strong in the field of stellar atmospheres (both normal and extended) where the physical ideas are made clear by good explanatory writing with a minimum of formal development which make it a good introduction to this field.

The section on interstellar material and particularly that on the internal constitution of stars are less satisfactory. Both ignore fundamental post-war western contributions to their subjects and these have been so important that large parts of these chapters are completely outdated.

The book is well produced but at $22.50 it can be doubted if this English translation will be accessible to more than a few of those who would find it most useful. One wonders if the same situation obtains in the Soviet Union!

LEONARD SEARLE

Introduction to the Mechanics of Stellar Systems by Rudolf Kurth. Pages 174; 8½ × 5¼ in. London, New York and Paris, Pergamon Press, 1957. Price $9.00.

Books on stellar dynamics are few, and this work "intended to serve as an introduction for more advanced students", to use the words of the author, will be welcome.

Chapter I outlines our knowledge of galactic structure, the concept of a stellar system, and the related observational data. In the following two

chapters, the author reviews the main assumptions, i.e. the validity of Newton's laws of motion, and the principles of the mechanics of systems of particles, then considers the possible approaches to the study of stellar systems, either as assemblies of gravitating particles or as gravitating continua, which are the subjects of chapters IV and V respectively.

The plan is very systematic, every chapter being subdivided into sections followed by a summary, a list of examples which are actually problems, and for the more interested reader, selected references with some comments on their content.

As an introduction to formal mathematical methods in stellar dynamics, this book will be valuable. Nevertheless, one would have wished a more extensive discussion of the observational methods and results which are of fundamental importance in the study of stellar systems.

The book contains few typographical errors, and is attractively bound.

PIERRE DEMARQUE

BRIEF NOTICES

Atmospheric Explorations edited by Henry G. Houghton. Pages x plus 125; 6¾ × 9 ¼ in. John Wiley and Sons Inc. and Technology Press of the Massachusetts Institute of Technology, 1958. Price $6.50.

The papers presented at the Benjamin Franklin Memorial Symposium of the American Academy of Arts and Sciences held in 1956. The papers deal with the most interesting developments in various fields of atmospheric exploration. Of interest to those who already have some knowledge of the physics of the upper atmosphere.

The Next 50 Billion Years by Kenneth Heuer. Pages 144; 5¾ × 8½ in. Viking Press, 1957. Price $3.25.

Speculations on the possible future of our world based upon modern scientific knowledge. Good light reading. Drawings by Chesley Bonestell.

A Quarter Century of Skyscraping 1932–1957 compiled and edited by Maribelle Cormack *et al.* Pages iv plus 44; 6 × 9¼ in. Skyscrapers Inc., 1957.

An account of twenty-five years development of a very lively amateur astronomers group. It shows what can be done by a small group blessed with energy and initiative.

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